Innovations to Reduce Livestock Methane Emissions[1]

Several innovations in development have the potential to significantly reduce methane emissions from livestock, which accounts for one-third of human-induced methane emissions and nearly 15 percent of all anthropogenic greenhouse gas emissions.

1. Context

The livestock sector is a key driver of climate change. It accounts for two-thirds of annual greenhouse gas emissions from agriculture. The largest share of livestock-related emissions today comes from production in upper-middle-income economies, while some high-income countries are large contributors in terms of per capita consumption (1, 2).

Demand for products from livestock is expected to grow. Consumer demand for beef is projected to increase by 80 percent by 2050. By the end of the decade, milk output is anticipated to grow by 9 percent in high-income countries and 33 percent in low- and middle-income countries.

Reducing methane emissions is an important component of the global response to climate change. Reducing methane emissions by 45 percent from 2010 levels by 2030 could prevent nearly 0.3 degrees Celsius of temperature rise by the 2040s.

Farmers currently lack sufficient incentives to invest in technologies to reduce their emissions as animal agriculture systems do not price greenhouse gas emissions in final products. As a result, commercial incentives for R&D on methane reduction and elimination technologies fall far short of the social value of these innovations.

2. Innovations to Reduce Livestock Methane Emissions

[1] This is a draft document that will be updated periodically until the publication of the Innovation Commission final report

Several innovations have the potential to significantly reduce methane emissions from livestock. Some of these innovations could also provide co-benefits to farmers by increasing productivity.

- **Feed additives that reduce methane emissions from livestock digestive systems.** These additives modify the rumen environment or interfere with methane generation and include algae, lipids, tannins, and other synthetic compounds, like 3-Nitrooxypropanol (3-NOP) and the synthetic bromoform-containing compound Rumin8. When dissolved in animal feed, these additives can alter the chemical reactions that generate methane emissions in the animal's digestive process.

- **Gene editing techniques to curb methane emissions and increase productivity.** These techniques could be used to improve breeding strategies or to edit the genes of livestock or of the microorganisms in their digestive systems that are responsible for generating methane emissions.

- **Approaches that improve the efficiency of meat and milk production in low-yield settings.** Existing technologies for animal management can be adapted to increase production efficiency in new settings. For example, advanced feeding software that computes the optimal diet for livestock is widely used in higher-income countries and could be adapted for producers in low- and middle-income contexts.

3. Potential impact and cost-effectiveness

Innovative feed additives could reduce methane emissions by up to 26-98 percent. Methane production consumes up to 12 percent of ruminants' gross energy intake, so reducing methane emissions via feed additives like 3-NOP could also increase productivity or milk quality by sparing energy in the digestive process and redirecting it towards animal growth and milk production (1, 2, 3, 4). Some feed additives may be challenging to produce at scale or may pose a toxicity risk that would call for further research before widespread use. Others, like 3-NOP, are becoming increasingly available in higher-income countries but have not yet sought regulatory approval in lower-income countries.

Selective breeding and gene editing could also substantially reduce emissions. These innovations could be used by producers who do not regularly use feed systems, such as pastoralists or extensive-system producers. Compared to nutritional strategies, genetic solutions result in long-term progress and therefore tend to be more cost-effective over time. Selective breeding for low-methane emission is in the early stages of development but could potentially reduce between 11 and 26 percent of emissions (based on preliminary consultations with experts). Gene-editing technology such as CRISPR-Cas DNA editing and genome-resolved metagenomics could be another tool to reduce methane emissions, allowing for precise changes in ruminant gut microbiomes. Further research on these gene editing techniques could evaluate their potential to reduce methane emissions and assess their effects on human and animal health.

Advanced farm-management practices, such as improved feeding software, could reduce methane emissions intensity in low-income countries by improving the efficiency of production. Innovations like ration formulation software that integrates local resources and is adapted for local livestock varieties could help farmers adopt these feeding practices. In high-income countries, animal diets are often formulated to optimize productivity, which reduces the emissions intensity per unit of output. For example, cattle farmers in California reduced emissions intensity of production by 45 percent relative to 1964, due in part to improvements in genetics and feed efficiency.

Further development of these innovations could improve their cost-effectiveness and affordability for wider use. Existing feed additives, like Bovaer®, have to be administered daily, making them impractical for many farmers, especially those whose animals graze in pastures. At USD 85-95 per cow per year, Bovaer® is also prohibitively expensive for many farmers in the absence of incentives that would reflect the environmental benefits. More research on these additives can also inform how long their effectiveness lasts over time.

These innovations could also increase productivity, especially for dairy products, which could in turn reduce emissions by reducing the number of cows. Dairy production in sub-Saharan Africa is more than five times as emissions-intensive per liter than production in North America or Europe, and cows in the region are only 5-7 percent as productive as their counterparts in North America or Europe. Increasing milk productivity per animal would reduce the number of cows kept for dairy production under plausible assumptions on price elasticities.

4. Potential pathways to scale

Governments and philanthropists could incentivize R&D through a range of instruments. Public support could expedite the development and testing phases of these innovations, through either up-front funding or through "pull mechanisms" that signal to private investors that there will be a future market for technologies that reduce livestock emissions. Pull mechanisms, such as prizes or Advanced Market Commitments, harness the energy and creativity of the private sector to address social priorities by committing to reward the development and take-up of new technologies.

Private actors could be incentivized to support methane emissions reductions from livestock with additional policy tools. Technologies to reduce methane emissions could generate social value far in excess of their commercial value, but farmers' private incentives to reduce methane lag far behind the social value of methane reductions, creating a role for policy tools, such as incentives, regulations, and tax measures to stimulate adoption.

By announcing in advance that they would adopt a package of incentives, taxes, and regulatory actions to encourage the use of cost-effective technologies to reduce emissions, high-income countries could incentivize innovation by signaling there will be demand for such products when developed. Such a package of policies could kick in when a pre-specified cost-effectiveness threshold—linked to the social value of averted emissions—is reached. Such regulations would presumably first apply to larger producers that are responsible for most emissions.

In principle, a cap and trade system for methane could be a complementary policy innovation to reduce emissions. In principle, “technology-agnostic” cap and trade systems for methane emissions could allow farmers to choose efficiently among methane reduction approaches and would create strong incentives for innovators to develop methane reduction technologies. However, a cap and trade system would require monitoring systems. Any such methane cap and trade program would presumably be introduced first in high-income countries. Cap and trade systems would typically be structured so that farmers would be allocated permits in proportion to current livestock holdings or emissions.

If a high-income country established a cap and trade program for methane, lower-income countries would have considerable incentives to establish their own monitoring systems and enter into agreements with high-income countries to sell emission permits. Assuming that permits were allocated based on the initial number of livestock, such trade could result in substantial financial flows to lower-income countries, as producers in high-income countries would have incentives to purchase permits from those in lower-income countries where production is typically more methane intensive per quantity of output, reducing herd sizes in lower-income countries. This, in turn, could potentially reduce over-grazing pressure and farmer-herder conflict.

5. Potential path forward

Governments and philanthropists should both make direct investments in R&D and consider other policy tools to accelerate innovation, including market shaping instruments and a cap and trade system.

Direct investments should be considered for R&D activities including:

- **Expanding testing of new feed additives.** Donors could fund on-farm testing across new settings of additives that have promising potential from laboratory results.
- **Test and expand selective breeding and approaches to edit the genes of the microbes that drive enteric methane emissions from livestock digestive systems**. Further research on animal genetics can improve our understanding of which traits in existing breeds are more effective for higher yields and/or lower emissions. Advancing our knowledge of microbiome genetic mapping in ruminant digestion could involve laboratory demonstrations to reduce methane in rumen cultures via microbiome community editing, followed by live animal trials.
- **Test methods to improve the production efficiency of existing technologies.** Testing the cost-effectiveness and take-up of improved farm-management practices and feed software to account for local feed availability and costs and local breeds.

In addition to funding for R&D, it would be beneficial to explore policies to harness the energy and creativity of the private sector in developing innovations to reduce methane emissions. This includes market shaping instruments, such as Advance Market Commitments and advance regulatory commitments. Governments could also explore the possibility of creating cap and trade systems for methane. These policy tools could allow farmers to choose efficiently among various methane reduction approaches, which in turn would incentivize innovators to develop methane-reduction technologies that farmers and consumers would accept.